



Foam Core Shielding for Spacecraft

NASA's Jet Propulsion Laboratory, Pasadena, California

A foam core shield (FCS) system is now being developed to supplant multi-layer insulation (MLI) systems heretofore installed on spacecraft for thermal management and protection against meteoroid impacts. A typical FCS system consists of a core sandwiched between a face sheet and a back sheet. The core can consist of any of a variety of low-to-medium-density polymeric or inorganic foams chosen to satisfy application-spe-

cific requirements regarding heat transfer and temperature.

The face sheet serves to shock and thereby shatter incident meteoroids, and is coated on its outer surface to optimize its absorptance and emittance for regulation of temperature. The back sheet can be dimpled to minimize undesired thermal contact with the underlying spacecraft component and can be metallized on the surface

facing the component to optimize its absorptance and emittance. The FCS systems can perform better than do MLI systems, at lower mass and lower cost and with greater volumetric efficiency.

This work was done by Marc Adams of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-43066

CHEM-Based Self-Deploying Planetary Storage Tanks

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A document proposes self-deploying storage tanks, based on the cold elastic hibernated memory (CHEM) concept, to be used on remote planets. The CHEM concept, described in previous *NASA Tech Briefs* articles, involves the use of open-cell shape-memory-polymer (SMP) foam sandwich structures to make lightweight, space-deployable structures that can be compressed for storage and can later be expanded, then rigidified for use.

A tank according to the proposal would be made of multiple SMP layers

(of which at least one could be an SMP foam). The tank would be fabricated at full size in the rigid, deployed condition at ambient temperature, the SMP material(s) having been chosen so that ambient temperature would be below the SMP glass-transition temperature (T_g). The tank would then be warmed to a temperature above T_g , where it would be compacted and packaged, then cooled to below T_g and kept there during launch and transport to a distant planet.

At the assigned position on the planet, the compacted tank would be heated above T_g by the solar radiation making it rebound to its original size and shape. Finally, the tank would be rigidified through natural cooling to below T_g in the planetary ambient environment.

This work was done by Witold Sokolowski and Kaushik Bhattacharya of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-43479

Sequestration of Single-Walled Carbon Nanotubes in a Polymer **The nanotubes would be solubilized for incorporation into lightweight composites.**

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Sequestration of single-walled carbon nanotubes (SWCNs) in a suitably chosen polymer is under investigation as a means of promoting the dissolution of the nanotubes into epoxies. The purpose of this investigation is to make it possible to utilize SWCNs as the reinforcing fibers in strong, lightweight epoxy-matrix/carbon-fiber composite materials. SWCNs are especially attractive for use as reinforcing fibers because of their stiffness and strength-to-weight

ratio: Their Young's modulus has been calculated to be 1.2 TPa, their strength has been calculated to be as much as 100 times that of steel, and their mass density is only one-sixth that of steel.

Bare SWCNs cannot be incorporated directly into composite materials of the types envisioned because they are not soluble in epoxies. Heretofore, SWCNs have been rendered soluble by chemically attaching various molecular chains to them, but such chemical attachments

compromise their structural integrity.

In the method now under investigation, carbon nanotubes are sequestered in molecules of poly(m-phenylenevinylene-co-2,5-dioctyloxy-p-phenylenevinylene) [PmPV]. The strength of the carbon nanotubes is preserved because they are not chemically bonded to the PmPV. This method exploits the tendency of PmPV molecules to wrap themselves around carbon nanotubes: the wrapping occurs partly because there ex-

ists a favorable interface between the conjugated face of a nanotube and the conjugated backbone of the polymer and partly because of the helical molecular structure of PmPV. The constituents attached to the polymer backbones (the side chains) render the PmPV-wrapped carbon nanotubes PmPV soluble in organic materials that, in turn, could be used to suspend the carbon nanotubes in epoxy precursors.

At present, this method is being optimized: The side chains on the currently available form of PmPV are very non-polar and unable to react with the epoxy resins and/or hardeners; as a consequence, SWCN/PmPV composites

have been observed to precipitate out of epoxies while the epoxies were being cured. If the side chains of the PmPV molecules were functionalized to make them capable of reacting with the epoxy matrices, it might be possible to make progress toward practical applications.

By bonding the side chains of the PmPV molecules to an epoxy matrix, one would form an PmPV conduit between the epoxy matrix and the carbon nanotubes sequestered in the PmPV. This conduit would transfer stresses from the epoxy matrix to the nanotubes. This proposed load-transfer mode is similar to that of the current practice in which silane groups are chemically

bonded to both the epoxy matrices and the fibers (often glass fibers) in epoxy-matrix/fiber composites.

This work was done by Richard A. Bley of Eltron Research Inc. for Johnson Space Center. Further information is contained in a TSP (see page 1).

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